TP 5078E

GSM Taxi

GSM PARATRANSIT VEHICLE TESTS

FINAL REPORT

Prepared for:
Transport Canada-Transportation
Development Centre

GSM Design Inc.

December 1983

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The contents of this report reflect the views of the contractor and not necessarily the official views or policies of Transport Canada, Transportation Development Centre.

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17. Abstract

This project covers the testing and evaluation of a specialized paratransit vehicle, the GSM Taxi. The prototype is based mainly on existing components, and has a front engine and rear wheel drive. The fiberglass body is supported by a tubular sub-frame, and a modular, perimeter bumper system provides body protection. The testing program evaluated the vehicle in the following areas: i) fuel consumption, ii) engine cooling system, iii) suspension and ride quality, iv) body and frame durability and integrity, v) interior space and layout. The overall design was basically sound, and recommendations for the next version are outlined.

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17. Résumé

Ce rapport rend compte de l'essai et de l'évaluation d'un véhicule de transport semi-collectif particulier, le taxi GSM. Doté d'un groupe de traction classique - moteur à l'avant, traction arrière -, le prototype de l'essai est essentiellement composé de pièces et d'éléments mécaniques de fabrication courante. Sa carrosserie en fibre de verre, montée sur châssis tubulaire, est protégée par un pare-choc modulaire faisant tout le tour du véhicule. Le programme d'essai a porté sur les aspects suivants: i) consommation de carburant, ii) système de refroidissement du moteur, iii) suspension et tenue de route, iv) durabilité et solidité du châssis et de la carrosserie, v) logeabilité et aménagement intérieur. Le rapport conclut que dans l'ensemble, le véhicule a été bien étudié, mais propose certaines modifications à apporter au prototype de la génération suivante.

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1. INTRODUCTION - THE GSM TAXI

The Montreal-based industrial design consulting firm, GSM Design Inc., decided on its own initiative in 1975, to investigate the apparent lack of a vehicle suitable for taxi service in North America. As the result of a detailed investigation of the requirements for a taxi, the design definition was worked out for a taxi in 1976, including all relevant interior and exterior dimensions, and a basic configuration. Subsequently, a full-scale mock-up was fabricated to confirm the design concept. A prototype vehicle was assembled and was first demonstrated at the Roads and Transportation Association of Canada Conference in September 1980, by Mr. M. L. Smith of GSM Taxi Ltd., a branch of the original firm. Transport Canada Report TP 2688, Innovative Paratransit Vehicle: the GSM Taxi, outlines the concept development and prototype details.

The GSM vehicle, shown in Figures 1 and 2, is a purpose-built taxi, fabricated with proven commercial components in the suspension and power train. The vehicle is of front-engine rear-drive design. The interior layout, as shown in Figure 1, has adequate space for up to five passengers, with two facing rearward on folding "jump seats". When a wheelchair is located in the passenger area, two passengers can be seated. Appendix I contains the prototype specifications.

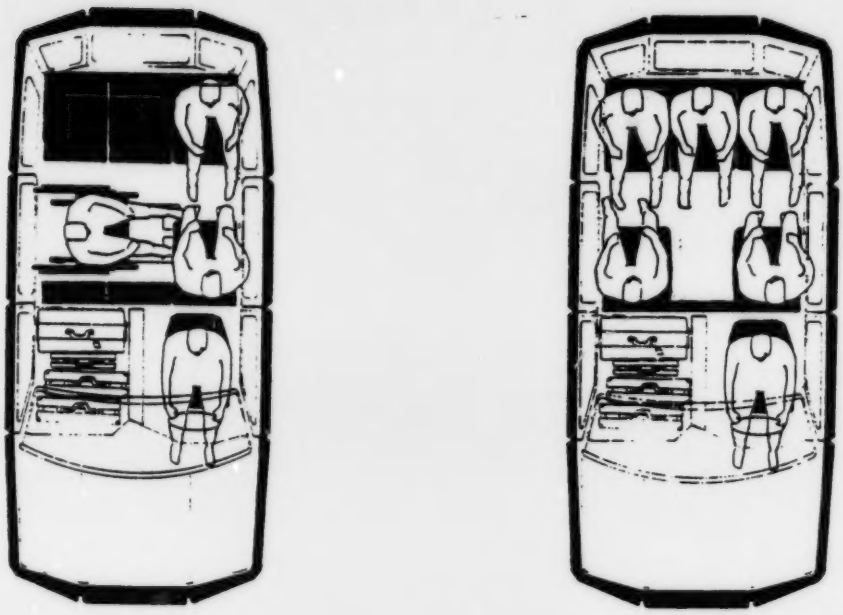

Figure 1.

Interior arrangement of GSM Taxi prototype.

The frame and body system, shown in Figure 2, are unique in a taxi application. The main frame consists of two longitudinal members connected by a series of cross-members. The suspension components are from a light duty truck. The front and rear suspensions utilize coil springs, hydraulic shock absorbers, and control arms. The rear coil springs and modified control arm system are designed to enable greater wheel travel for improved ride and stability over rough surfaces.

The engine is an in-line, six-cylinder GM 4.1 litre gasoline unit, coupled to a GM 400 automatic transmission. Future engine options could be a GM V-6, with diesel or propane versions.

A sub-frame is fitted to the main frame to support the perimeter bumper system, which minimizes body damage and greatly improves the repairability of the body. This bumper system (patented by GSM[1]) incorporates components which protect the body against impacts, between 30 and 85 cm above ground level, utilizing urethane fabricated by the RIM (reaction injection moulding) method. The prototype used vacuum formed ABS panels due to mold cost considerations, but the principle is the same. The front of the vehicle is protected by a central bumper, plus two corner segments.

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[1] Registered 1982, Guillon, Smith, Marquart Ltee. No. 49437 and U.S. Pat. D260627.

The wheel arch sections are made of the same material and a common design accommodates all four corners. Similarly, a common module is used for each of the four doors. The rear of the vehicle is fitted with a bumper system identical to the front, so that only four moulds are required to make a total of fourteen components used in the perimeter bumper system.

As shown in Figure 2, the floor and seat areas are moulded in one piece of reinforced fibreglass. Above the bumper line, a moulded fibreglass upper body section is bolted to a rigid frame, accommodating the front and rear windows. The front hood is a one-piece fibreglass section which opens up to expose the entire engine compartment for easy access and service. The entire of the body above the perimeter bumper is painted with a high gloss automotive finish.

The seats, which are easily removable, are covered with heavy-duty vinyl. The interior of door panels, division panels, and kick-rails are covered in a carpet-like material to withstand repeated scuffing and resist soiling. In the prototype, there is a permanent partition between the driver and the passengers for privacy and security. The passenger area has separate controls for heating and ventilation to ensure comfort. Luggage is stored next to the driver on the curb side of the vehicle for easy and safe access by the passenger and the driver. The driver's seat has a high

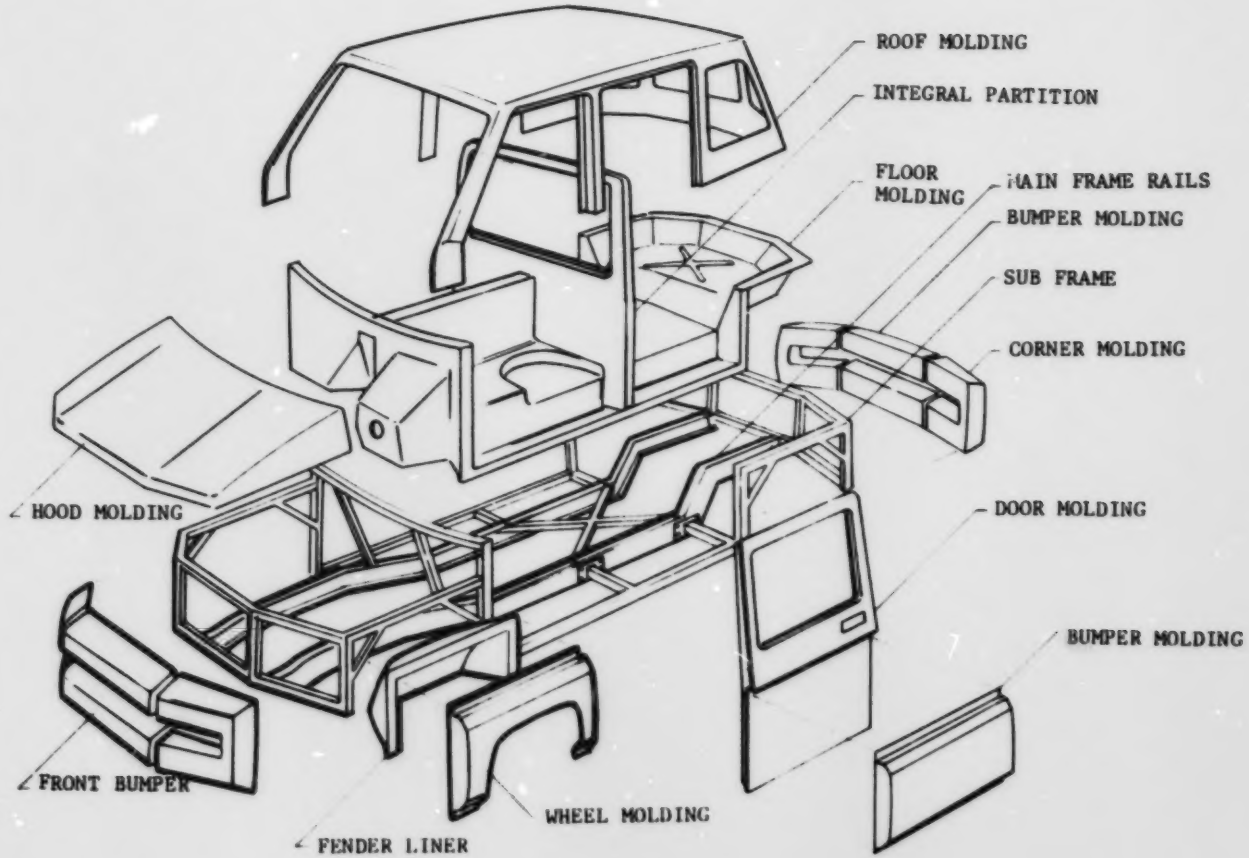

Figure 2. Major Components of Prototype Vehicle.

back, minimizing driver fatigue during long periods on duty. The height of the vehicle improves driver and passenger visibility, making for safer driving and more enjoyable trips. The brake system is heavy-duty to withstand the severe duty of taxi operation.

The GSM taxi can accommodate wheelchairs, using a removable ramp stowed in the luggage space beside the driver. The single wheelchair is restrained to the floor by a GSM designed mechanical restraint system, with the wheelchair in the lateral position, facing the roadside of the vehicle.

The design concept of the GSM taxi is such that a "stretching" of the basic vehicle into six and eight door versions is feasible, with wheelbases of 372.1 cm and 614.7 cm respectively, in comparison with the 255.3 cm wheelbase of the 4-door version. Other commercial uses for the vehicle are also foreseen, beyond only the carrying of passengers.

Since the prototype vehicle contained a number of novel ideas, they, along with the standard vehicle parts, required a test programme to prove their effectiveness, durability and suitability. Following the vehicle development project referred to in TP 2688, Transport Canada approved funding of a test programme in November 1980.

2. TEST PROCEDURES AND RESULTS

The objective of this project was to evaluate certain novel aspects of the GSM prototype, and to establish a base-line reference against which future paratransit vehicles could be compared. The use of existing drive train and suspension components in taxi duty for the first time also required close evaluation. The results could then be applied to subsequent versions of the GSM vehicle concept, as well as other paratransit vehicles, where appropriate. It was not possible to operate the prototype in actual revenue service, due to the legal requirements for taxi permits, etc.

Also, the nature of any prototype vehicle is not the same as a fully-developed and refined vehicle, so passenger reaction would be affected by these imperfections.

The areas of study concentrated on were:

1) Fuel consumption.

2) Radiator and engine cooling system performance.

3) Suspension performance and ride quality.

4) Body and frame durability and integrity.

5) Passenger reaction to the layout and available space.

6) Safety restraint devices.

2.1 Fuel Consumption

Economy of operation is a major factor in selection of any commercial vehicle. The cost of fuel for the GSM vehicle oncept would be important in its overall acceptance by the taxi industry. The prototype engine was the same as that used in current taxi sedans and vans, but the weight and air resistance were closer to that of a van.

Comparative fuel consumption tests were to be run on bias ply and radial ply tires. Many taxi fleets have used bias ply tires due to the softer ride and lower purchase price. At urban traffic speeds, the tire life and fuel consumption were not sufficiently different to make radials more economical. Improvements in suspension bushings, higher fuel costs and lower prices for radials in the last year or two have changed this. Taxi fleets now use radials almost exclusively. Use of radial ply tires was therefore felt to be of lesser importance during the consumption tests.

A closed test track and precise instrumentation were not available for fuel consumption tests, so all driving was conducted on public roads. This also gave the most realistic results. Driving was conducted in downtown Montreal, with occasional highway and expressway trips being measured as well. Passenger load varied from none to four passengers, with two on average. During the testing, front wheel alignment was required, as well as minor engine refinements, and these may have slightly affected the results.

Inexpensive bias ply tires were used on the vehicle initially, but balance problems persisted, so top quality, steel-belted radials were installed. The project work statement indicated tests were to be performed at both 165 kPa and 193 kPa tire pressures. Experience showed that the higher pressure was necessary for best handling and tire life, due to the vehicle weight, so this was used most of the time. Fuel consumption results are shown in Table 1.

Tire size of the bias tires was H 78-15, and of the radials (Michelin-X) was 215/75R-15.

Vehicle speed	Bias Ply	Radial Ply
30 - 50 km/h	20.0	17.5 - 22.0
95 - 105 km/h	14.0 - 15.5	14.0 - 16.5
Steady 95 km/h	———	13.0 - 14.0

Table 1

Fuel Consumption Results, litres/100 km

(All figures at 193 kPa tire pressure)

2.2 Engine Cooling System

The operating temperature of an automotive engine depends on (i) the characteristics of the engine, (ii) the power demands on it, and (iii) the performance of the cooling system. Assuming the first two items cannot be varied, the test centered on monitoring the engine temperature under a number of ambient conditions, and then evaluating various changes to the radiator and the air flow through it.

The initial radiator on the prototype vehicle was a custom-made unit, smaller than the one supplied with the engine. This was due to space limitations within the frame rails and body panels. During trial runs, the engine tended to become hot during summer stop and go driving, although the system pressure never exceeded the limit of the radiator pressure cap. This represented a maximum temperature of approximately 112° C. No fan shroud had been installed, due to space limitations.

A new radiator was fabricated and installed, which had a slightly larger height and width, plus a triple core rather than the two-layer core of the original. The grill opening was also enlarged to the maximum allowable by the front bumper moldings. Engine temperature remained at 82° C at highway speeds, between 90° C and 95° C while idling, and about 10° C higher when the air conditioning was operating.

Hot weather engine temperatures (25° C ambient) were still rather high however, so the transmission fluid cooling connection was removed, and a separate transmission fluid cooler was installed in front of the radiator. This subsequently reduced the engine temperature by about 4° C, and improved transmission cooling. Even with these changes, however, the engine temperature approaches 110 ° C during hot weather, when the vehicle is idling for sustained periods with the air conditioning operating. This can be corrected with some of the changes outlined in the section on conclusions.

2.3 Supervision Performance and Ride Quality

The GSM Taxi concept is based on the use of standard, available components for the chassis and suspension system, wherever possible. The prototype testing was to prove the suitability of these components, and to allow selection of the best spring and shock absorber characteristics for taxi use.

The front suspension used all the parts as supplied with the light-duty Chevrolet pick-up truck. Front axle weight was approximately the same as the original pick-up truck, so spring and shock absorber rates were left unchanged. The results with the front suspension have so far been quite satisfactory. Vehicle handling and steering response is good, and no changes are anticipated.

The rear suspension required the use of coil springs and control arms, rather than the truck leaf springs, to minimize rear overhang. The system used four control arms and coil springs from a Chevrolet sedan. The control arm location was modified by attaching the upper arms at the outer ends of the axle, rather than in the normal inner position. The first springs used were not adequate for the load, and bottomed too easily when loaded on rough roads.

Heavier springs were installed which improved on the problem, but gave a harsh ride. The original springs were reinstalled, with new shock absorbers incorporating inflatable air chambers to take part of the load. This has been quite satisfactory for any passenger loading condition. The inflatable shocks are particularly helpful in keeping the ride height constant for varying passenger loads, although the inflation is not automatic.

The shock absorber mounting brackets were too weak as originally installed, and were replaced with a stronger design, at approximately 28,000 kilometres. No further problems have occurred.

The change from bias ply to radial ply tires caused a slight increase in ride harshness. The rubber suspension bushings were not the type generally used with radials however, so this was to be expected. Refinements in suspension bushings and radial tires should minimize tire harshness with future vehicles.

2.4 Body and Frame Durability and Integrity

The body and frame testing consisted of close monitoring of the various components to locate structural weaknesses, excessive movement or fatigue in any of the parts. Taxi operation in urban areas is one of the severest uses for any vehicle, and standard passenger sedans do not usually last more than three years. The GSM vehicle construction concept would have to offer a service life closer to ten years to be feasible, so the road testing would help to evaluate this.

The prototype was not road tested on a closed track or road before street operation, so there were a number of minor adjustments to be made in the first few miles. These consisted mainly of tightening fasteners and rectifying leaks between panels. The door sealing gasket required adjustments in thickness to ensure watertightness, and the inner wheel well liners required additional sealing material. This would be expected on a prototype of a new design, but would be eliminated on production vehicles.

The main frame structure and subframe have shown no structural weaknesses or faults after 44,000 kilometres, 15,000 of which have been accumulated in downtown Montreal. A number of fasteners became loose, but were retightened with shakeproof washers. No loose fasteners have since been discovered, and some of the original ones may not have been property tightened. No

serious corrosion has occurred after three winters of service.

The fiberglass roof, hood and interior floor shell moldings have performed without cracking or any deterioration. The floor has supported some heavy loads, and has not been structurally affected.

The perimeter bumper moldings and interior door liners were made of vacuum-formed ABS, rather than fiberglass-reinforced polyester. This material shrinks more in very cold temperatures than fiberglass, and must be taken into account. Two of the door liner panels cracked, due to too tight a fit over the door frame. Some cracking also occured in the bumper panels, which were tightly held by fasteners to the doors and subframes. No stress problems were encountered due to hot weather temperatures.

The moldings have received some minor impacts, with no resultant damage. One collision resulted in a broken bumper molding, which was easily replaced, with no damage to the subframe structure.

2.5 Interior Space and Layout

One of the main advantages offered by the GSM Taxi concept is the increased passenger space over conventional taxis. Although revenue service with actual paying passengers was not possible, a good

evaluation of the vehicle interior layout was obtained from various riders. Trips were made in downtown Montreal as well as expressway trips, and the passengers' reaction would be essentially the same as that of paying riders. The vehicle was also shown to several taxi fleet owners and drivers.

Overall reaction to the space and seating arrangement was very good. The headroom was especially appreciated, plus the ease of entry and exit. The folding jump seats were well-liked, although some felt that the backrest on them was too upright. Additional handrails were added inside the rear doors to aid the elderly, and for wheelchair passengers to transfer to the seat. The overall ride height was well-liked, as it gave a better view of the surroundings and a feeling of security to passengers. The rear seat was found to be slightly too high and upright by some passengers. The rear seat width (170 cm) was found to be comfortable for three average-sized adults.

The driver's space was limited, with the seatback being more upright than many drivers preferred. The instrument layout and optional items such as the radio were well-received. The fixed bulkhead between the driver and passenger areas was not liked by all drivers, as it blocked access to the baggage area in front. The "A" pillar was thicker than necessary and reduced visibility slightly.

The capacity to accommodate a wheelchair was felt to be a strong feature of the vehicle. Wheelchair passengers felt secure while riding in the transverse position, due to the close proximity of the seat and bulkhead. A simple and secure tie-down was devised, which ensured that the wheelchair could not move. The original ramp consisted of two separate rails, but this was replaced with full-width ramp. This was easier to use, as the driver could stand on the ramp as he pushed the wheelchair up or down.

The flow of fresh air into the passenger area was not sufficient for all needs. The windows were fixed in the rear doors, and air ducting into the area was minimal. Heating and air conditioning capacities were somewhat below the capacity required for extreme temperatures. The air leaks around the doors were noticeable under these conditions, so probably contributed to the problem.

2.6 Safety Restraint Devices

Safety restraints will be an important feature of the production vehicle. Lap and shoulder belts were installed on the rear seat, but a formal evaluation of their use and comfort was not made. The seat design for the next generation vehicle will incorporate lap and shoulder belts into the rear seat, and lap belts into the jump seats.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 Fuel Consumption

A major factor in the fuel consumption results was the weight of the vehicle, which was approximately 1,600 kg. This was some 500 kg over the intended weight for the concept design. A weight reduction of this amount would reduce fuel consumption by about 15%. Newer transmission designs, with four speeds and a mechanical lockup in top gear would help in both city and highway driving. Changes to the body, including lowering overall height, and attention to body shape would also contribute.

Engine improvements, such as electronic fuel injection, coupled with the most recent designs of cylinder head, etc., would help as well. The estimated consumption figures for the next generation vehicle would likely be in the order of 20% - 25% better than those for the current prototype. It must be kept in mind, however, that it is principally an urban, low-speed vehicle, and not a highway vehicle. Diesel or propane fuel is another alternative to reduce costs as well.

3.2 Engine Cooling System

A number of improvements could be incorporated into the cooling system. The radiator is at about the maximum

size, but the air flow can be increased several ways. The grill open area could be increased, a shroud could be installed, and the fan speed could be increased. These would have sufficient effect that any overheating should be eliminated. An electric fan is an alternative, as well as possibly increasing the water pump speed to improve water flow through the engine and heating system.

3.3 Suspension Performance and Ride Quality

The suspension system on the prototype generally performed well, other than the bottoming of the rear coil springs. This is an inherent problem with this type of vehicle, which must provide good ride quality while adapting to a wide range of payloads. Properly-matched, air-assisted shock absorbers are one solution, but a full air spring system would probably give the best result. A fully-automatic, air spring, self-levelling system is now used on the Lincoln Continental. A similar system is being investigated for the next generation GSM vehicle. Variable rate coil springs are another possibility, and coupled with inflatable shock absorbers, they may provide an effective solution as well.

3.4 Body and Frame Durability and Integrity

The overall design of the frame and fibreglass components have proven to be sound and trouble-free. The basic design will be carried over to the next prototype with little modification. The doors and liners will be made to fit more accurately, and liner panels will use a grade of resin which does not contract excessively in cold temperatures. Fasteners will also allow for expansion and contraction of the molded parts.

The bumper components will be molded using the RIM process, which is not as susceptible to temperature changes, and will be more resilient and energy-absorbing than the ABS components. The bumper system has shown itself to be effective and practical, and it will be used with few changes on the next vehicle (other than the use of RIM parts).

3.5 Interior Space and Layout

The interior arrangement and overall dimensions are quite adequate, and no increase or change is necessary. The seat will be redesigned to be lower, and with more rearward slope to retain passengers better. Ventilation will be improved, possibly with sliding or roll-down windows. With improved door seals, heating and cooling should be much improved.

The driver's space will be increased with an adjustable backrest on the seat. The partition will be an optional item, depending on the requirements of the particular taxi fleet. When the vehicle design is put to uses other than as a taxi, such as a limousine, the baggage area could also have a seat. If no partition is present, the jump seats would be installed inside the rear doors.

The wheelchair accommodation works well, but when no partition is present, it is hoped that a wheelchair user will be able to face the wheelchair forward, as this is the most preferred position. The current ramp and tie-down are quite effective, with the only problem being the storage space for the ramp. The luggage area is currently used, which interferes with articles being carried in this area.

Appendix "A"

PROTOTYPE SPECIFICATIONS FOR GSM TAXI

1. General

Curb weight, kg	1600
Weight distribution, front/rear %	54/46
Wheelbase, cm	280.7
Track, front/rear, cm	165/165
Length, cm	427
Width, cm	191
Height, cm	191
Ground clearance, cm	18
Overhang, front/rear, cm	81
Usable trunk space, m^3	0.7
Fuel capacity, litres	95
Bumper height, cm	40-51
Headlight center, height, cm	63.5
Tail light cluster center, height, cm	63.5
Sidemarker lamps, height, cm	94
Reflex reflectors, height, cm	94

2. Engine

Type	stock GM OHV in line 6
Displacement, cc	4097
Brake horse power @ rpm net	100 @ 3600
Torque @ rpm (175 lb. ft)	237 N.m @ 2000
Carburation	1 Rochester MV
Fuel Requirement	Regular No-lead
Exhaust system	Single aluminized
Emission control equipment	Catalytic converter

3. Drivetrain

Transmission ..... GM 400 automatic

Final drive ratio 3.4:1

4. Chassis & body

Layout ..... Front engine/rear drive

Body/frame ..... Semi-monocoque - steel rails & reinforced fiberglass body

Brake system ..... GM 32 cm diam. discs front 28.3 x 7 cm drums rear (vacuum assis.)

Tires ..... Bias H 78-15/Radial 2.25-15

Wheels ..... 28.3 x 7 cm

Steering ..... Power assisted: recirculating ball gear parallelogram linkage

Front suspension ..... Independent coil springs, upper & lower 'A' - arms, anti-roll bar, 1" diam. tube shocks

Rear suspension ..... Live rear axle, hypoid drive, coil springs, 4 outboard upper & lower control arms, 1" diam. shocks

5. Accommodation

Seating capacity ..... 1 driver
5 passengers
(3 + 2 occasional)

Seat width, front/rear, cm. 56/140

Headroom front/rear, cm. 102/102